groundwater

Underground water found in the pore spaces of rocks and sediments in fully saturated zones is called groundwater. Although not used as extensively as surface water worldwide, groundwater is the most important source of water for rural domestic use. In many areas groundwater constitutes the largest reserve of potable water; it provides drinking water for about half the population of the United States. In arid regions, such as the Middle East, groundwater is the only source of water for irrigation and municipal and industrial use. Even in humid regions, such cities as Miami, Tokyo, London, and Houston extract large amounts of groundwater for various purposes. Groundwater is generally preferred to surface water because it is less contaminated by pathogenic organisms, is usually found only a short distance below the surface, has nearly constant temperature, and is available in many areas even after several years of severe DROUGHT.

ORIGIN

Most shallow groundwater originates directly from the downward percolation of small amounts of rain and snowmelt into the subsurface. Very deep groundwater, on the other hand, may be held in pore spaces in an almost static condition for thousands or millions of years. Some of this water contains large amounts of dissolved salts and may be ancient seawater trapped during the formation of enclosing rocks. In most geologic settings, however, the deep, saline water has migrated slowly, and it does not represent the water trapped when the rocks were formed. In volcanic areas, small amounts of water may come from bodies of molten igneous rock (magma) in the deeper subsurface. Even in areas of hot springs and geysers, however, the amount of water derived directly from molten rock sources is generally less than 1% of the total amount of hot water discharged at the surface.

MOVEMENT

The rate of movement of groundwater is controlled by the permeability of the rock or sediment in which it is contained (see PERMEABILITY, ROCK) and by the slope of the WATER TABLE, just as a river's flow rate depends on the slope of the riverbed. The movement of groundwater is much slower than that of surface water, however--usually only a few centimeters per day. This slow movement is an important characteristic, for it means that water is held in the ground, available for human use, for relatively long periods before making its way to the sea. If suitable AQUIFERS are present, groundwater may travel hundreds of kilometers from its source region.

DISCHARGE AND RECHARGE

Groundwater is discharged at the surface through SPRINGS, by slow, diffuse seepage into streams and lakes, by vegetation that sends roots into the water table, and by wells and drainage galleries. Vegetation can discharge very large amounts of water vapor into the atmosphere, and may be a serious drain on water supplies in arid climates.

Most precipitation either returns to the atmosphere by evapotranspiration or runs off the surface into nearby stream channels. In most areas less than 10 cm (4 in) per year percolates through the soil to eventually recharge the groundwater reservoir. In arid regions the amount of water that eventually becomes recharge averages less than 1 cm (3/8 in) per year. Unusually high recharge rates, more than 100 cm (40 in) per year, may take place locally in humid regions where surface materials are very permeable, as in streambeds and recent lava flows.

The natural balance between recharge and discharge, part of the HYDROLOGIC CYCLE, can be drastically upset by pumping too much water from wells, particularly near large cities and in such regions as in the southwestern United States, where water is pumped for irrigation. Natural recharge may be so slow in arid regions that water that has taken several thousand years to accumulate may be exhausted by deep wells in one or two decades. The drop in groundwater levels in many areas exceeds 3 m (10 ft) per year because of overextraction. A potentially dangerous side effect of groundwater depletion is earth subsidence, which occurs when the ground sinks and deep fissures form as the result of too much water being pumped from below the surface.

QUALITY

All groundwater, including that fit for drinking, contains dissolved chemical substances. The exact composition of groundwater depends on the original composition of the precipitation before it enters the ground, the nature of the soil that first comes in contact with the precipitation, the minerals that make up the rocks in the saturated zone, the water temperature, and the presence of human contaminants. Total dissolved substances in groundwater range from about 20 to more than 300,000 milligrams per liter.

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The temperature of groundwater almost everywhere is only 1 to 5 C (1.8 to 9 F) degrees higher than mean annual air temperature. Exceptions are found in HOT SPRINGS, which obtain added heat from either volcanic activity or exceptionally deep circulation in the subsurface.

CONTAMINATION

Almost all human activity alters water quality somewhat, but not necessarily as a result of pollution by human materials. For instance, in some areas reduction of water levels in the subsurface by pumping may allow saline water to flow toward the wells; this happens most often in coastal areas. Domestic waste (sewage and solid trash), however, is, worldwide, the most serious source of groundwater contamination. Although within the acceptable range of potable water in terms of chemical composition, sewage commonly contains excessive amounts of solid organic material and large numbers of pathogenic organisms. Filtration of solids and adsorption of heavy metals in solution by soils and other natural materials may render sewage potable by the time it reaches groundwater supplies.

Unfortunately, natural materials can only filter and absorb so much. For this reason, sewage-disposal systems for more than a single-family residence must be more elaborate than the usual septic tank. Solid trash, if accumulated in large amounts in humid regions, is a major source of concentrated pollution. Water moving through the decaying trash can dissolve thousands of milligrams per liter of noxious material, including poisonous metals and flammable methane. Modern sanitary landfills are carefully engineered so that surface water cannot move through trash and enter the groundwater supply.

Other common sources of groundwater contamination are industrial wash water, fluids used in metal plating, pickling brines, and strong acids. Agricultural practices can also pollute groundwater. The three most common agricultural sources are animal waste in barnyards and feed lots, chemicals such as ammonia fertilizers, and excess return irrigation water, which is needed to keep salts from accumulating in the soil horizon.

The U.S. government has adopted measures to reduce groundwater contamination and protect public health. In compliance with the Safe Drinking Water Act of 1974, which was amended in 1986, the Environmental Protection Agency has set standards limiting the presence of eight hazardous chemicals, including benzene, carbon tetrachloride, and vinyl chloride, in drinking water. The Clean Water Act enacted in 1987 provides funds for the control of such runoff pollutants as fertilizers, pesticides, and petroleum products.

DEVELOPMENT

Most groundwater used today comes from wells, the rest from springs and horizontal collection galleries. The first stage in developing a groundwater supply is to inventory the existing wells and springs and, with geologic and geophysical studies, to estimate the groundwater resources available in the region. Test drilling is then conducted to check on the data that have been gathered, and previously existing wells and new wells are pumped to determine the storage and water-transmitting properties of the subsurface materials. At this point it was formerly customary to drill wells for final groundwater production. It has become increasingly common to construct mathematical models to simulate future behavior of the groundwater reservoir. These models can then be used to manage the groundwater resources. Agricultural scientists are evaluating new irrigation techniques and co nstructing models in studies of groundwater quality. This research will help ensure the beneficial use of groundwater, a precious resource.

Stanley N. Davis

Bibliography: Kenski, H.C., Saving the Hidden Treasure: The Evolution of Ground Water Policy (1990); Kovacs, G., et al., Subterranean Hydrology (1981); La Fleur, R. G., ed., Groundwater as a Geomorphic Agent (1984); Pinnerker,. E. V., ed., General Hydrogeology, trans. by D. E. Howard (1983); Raghunath, H. M., Ground Water (1987); Van Der Leyden, F., et al., The Water Encyclopedia, 2d ed. (1989).

See also: ARTESIAN WELL; POLLUTION, ENVIRONMENTAL; POLLUTION CONTROL; WATER QUALITY; WATER RESOURCES; WATER SUPPLY.

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